Integrated Cost / Schedule Risk Analysis

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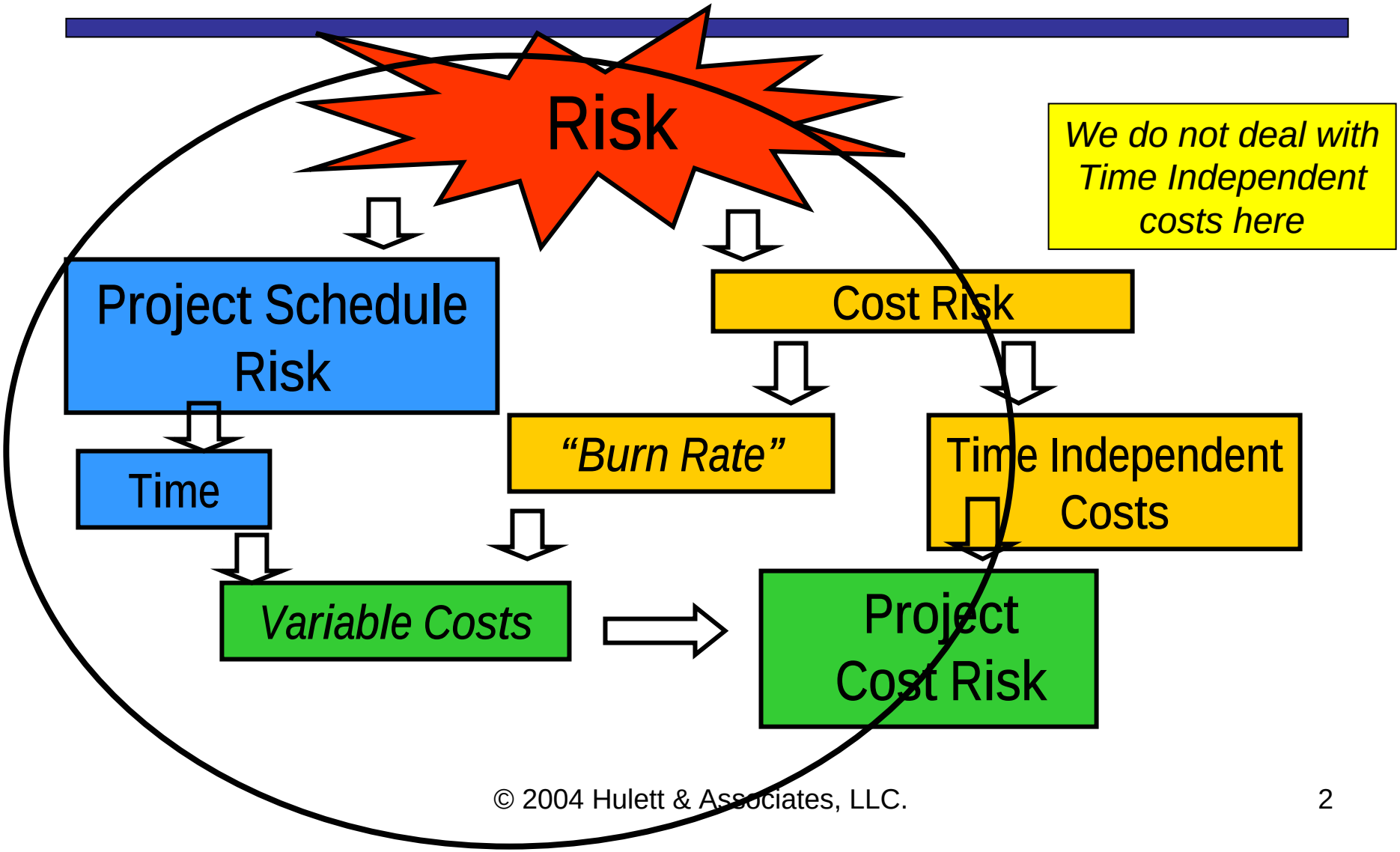
Cost and Schedule Risk Integration



Cost Estimating Basics

- Cost estimates can be constructed by multiplying:
  - People assigned
  - Daily Rate
  - Duration
- Uncertainty in any of these variables leads to uncertainty in project cost estimates
- Cost risk estimating can be more accurate and the reasons for risk better illuminated when time and cost factors are addressed individually rather than as one cost uncertainty distribution

Simple Equation for Cost of an Activity

	Base Cost Estimate
Duration	40
People average	5
Daily Rate average	800
Total Cost	160,000

How Likely are We to Overrun the Estimate of $160,000 for this Task?

Uncertainty in Time *and* in Cost Elements

		Low	ML	High
Duration	40	30	40	60
People	5	3	5	8
Daily Rate	800	750	800	875
Total Cost	160,000			

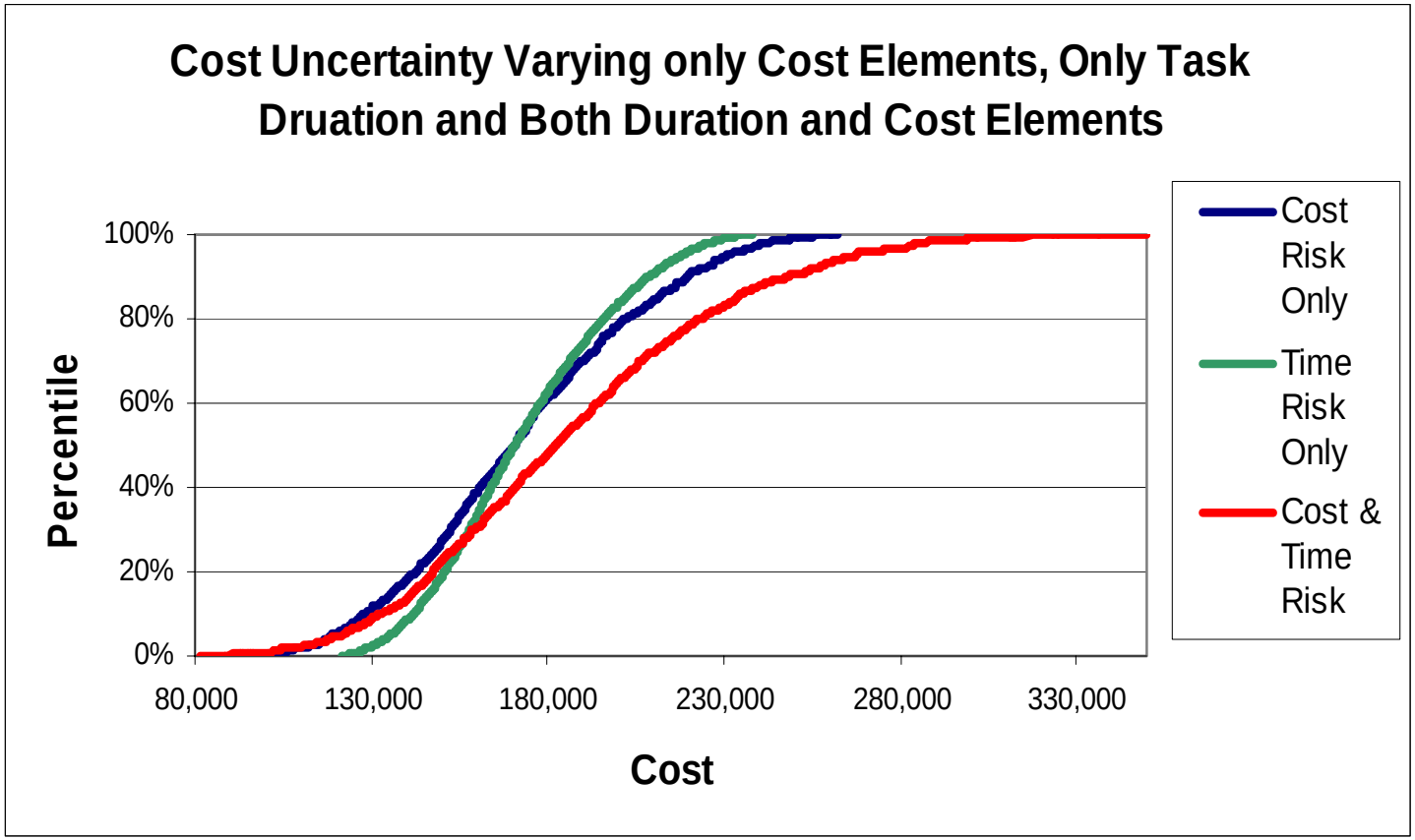
Compare Cost and Time Uncertainty Results

Cost Risk			
Percentile	Vary Only Cost Elements	Vary only Task Time	Cost and Time Vary
	(000)		
0%	98.0	121.6	81.6
10%	128.5	141.9	132.6
20%	142.7	150.9	147.6
30%	152.4	157.9	159.1
40%	160.9	164.0	171.0
50%	170.8	170.7	182.7
60%	178.8	178.0	193.8
70%	190.1	186.3	206.3
80%	202.3	196.0	223.7
90%	219.5	209.0	248.0
100%	262.4	238.0	350.1

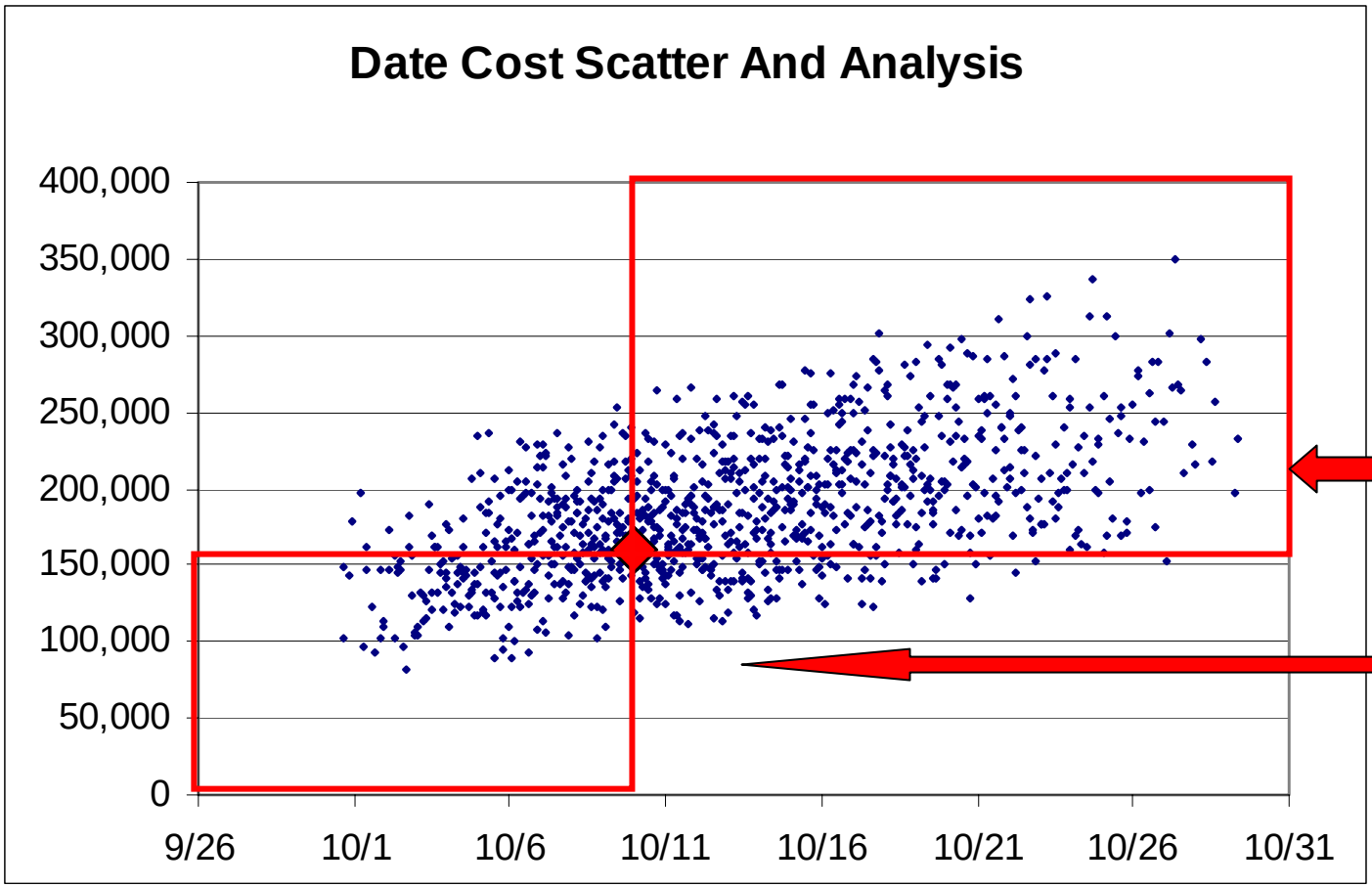
$160,000 is 31%
(vs. 33%-39% with cost or time separately)

80th Percentile is NOW
$223.7 thousand
(vs. $202-209 thousand)

Varying both Cost and Time Elements Provides a More Accurate Picture of Cost Risk



Time / Cost Pairs for 1,000 Iterations, Compared with the Target Values



Overrun Cost is 70% likely

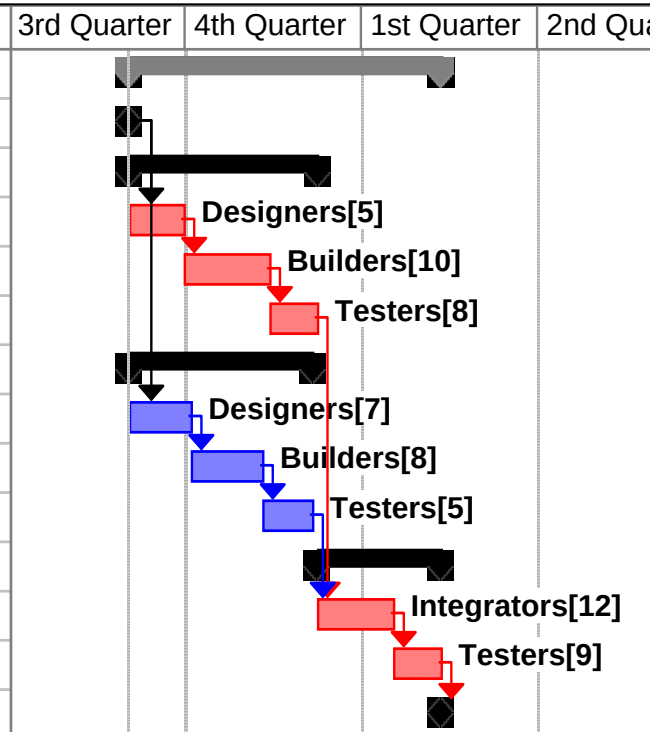
Overrun time (10/10 = 40 days) is 67% likely

Overrun cost and time is 54% likely

Meeting both cost and time is 17% likely

Cost / Schedule Risk using a Schedule with Detail and Summary Activities

ID	Task Name	Duration	Start	Finish
0	**Integrated Cost-Schedule**	**163 d**	**9/1**	**2/10**
1	Start	0 d	9/1	9/1
2	**Component 1**	**98 d**	**9/1**	**12/7**
3	Design 1	28 d	9/1	9/28
4	Build 1	45 d	9/29	11/12
5	Test 1	25 d	11/13	12/7
6	**Component 2**	**95 d**	**9/1**	**12/4**
7	Design 2	32 d	9/1	10/2
8	Build 2	38 d	10/3	11/9
9	Test 2	25 d	11/10	12/4
10	**Integration and Test**	**65 d**	**12/8**	**2/10**
11	Integrate	40 d	12/8	1/16
12	System Test	25 d	1/17	2/10
13	Finish	0 d	2/10	2/10



Schedule is defined and statused at detail level, whereas cost is often estimated and collected at summary level

Computing Schedule Risk when Cost and Schedule are in Separate Programs: Example

- Using Risk+®, simulate the MS Project schedule, collecting duration results for the summary activity
- Inputs
  - 3-point estimates for duration of tasks
  - Distribution shape for each task
- Outputs
  - Duration results for the summary tasks
  - Summary activity duration for each iteration

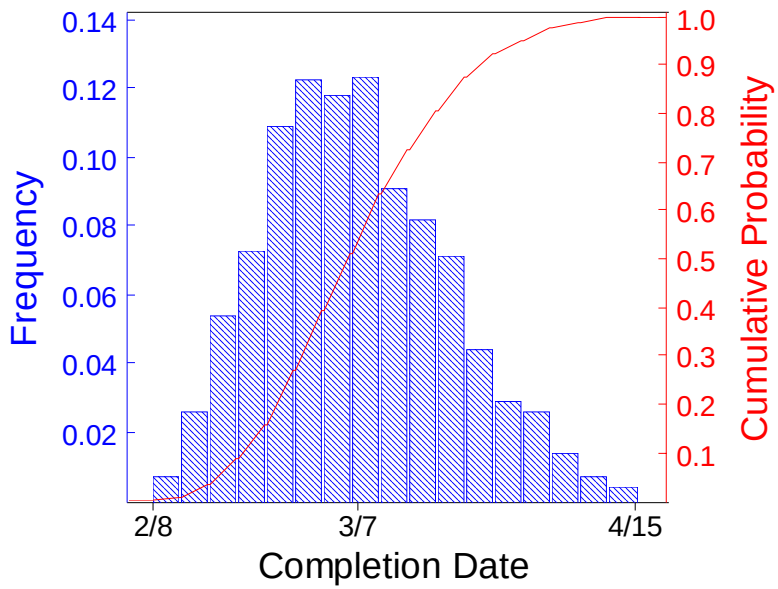
Inputs to Schedule Risk Analysis

Schedule Risk Inputs					
	Report ID	**Min Rdur**	**ML Rdur**	**Max Rdur**	**Curve**
Component 1	**1**				
Design 1	0	20 d	28 d	45 d	2
Build 1	0	35 d	45 d	55 d	2
Test 1	0	20 d	25 d	50 d	2
Component 2	**1**				
Design 2	0	24 d	32 d	43 d	2
Build 2	0	35 d	38 d	47 d	2
Test 2	0	20 d	25 d	45 d	2
Integration and Test	**1**				
Integrate	0	35 d	40 d	55 d	2
System Test	0	20 d	25 d	60 d	2

Schedule Risk Analysis for Integration and Test

Date: 9/1/2003 4:05:56 PM
Samples: 1000
Unique ID: 18
Name: Integration and Test

Completion Std Deviation: 12.72 d
95% Confidence Interval: 0.79 d
Each bar represents 4 d



Completion Probability Table

Prob	Date	Prob	Date
0.05	2/17	0.55	3/8
0.10	2/21	0.60	3/9
0.15	2/23	0.65	3/11
0.20	2/25	0.70	3/13
0.25	2/27	0.75	3/16
0.30	2/29	0.80	3/18
0.35	3/1	0.85	3/21
0.40	3/3	0.90	3/25
0.45	3/4	0.95	3/31
0.50	3/6	1.00	4/15

Dates do not equate to durations for this activity because of uncertainty in the predecessor activities

Duration Results for Summary Tasks

Schedule Measure	Scheduled	Mean	Standard Deviation
	(days)		
Total Project	163	176.6	9.2
Component 1	98	101.0	8.0
Component 2	95	101.3	7.8
Integration and Test	65	71.0	6.3

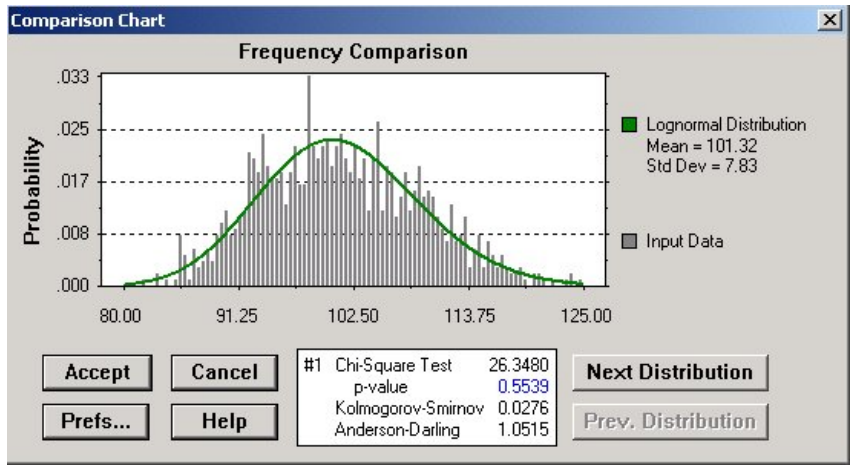
For the cost risk we use simulation results for durations of summary tasks or phases. This is a table summarizing duration results.

Computing Schedule Risk when Cost and Schedule are in Separate Programs (continued)

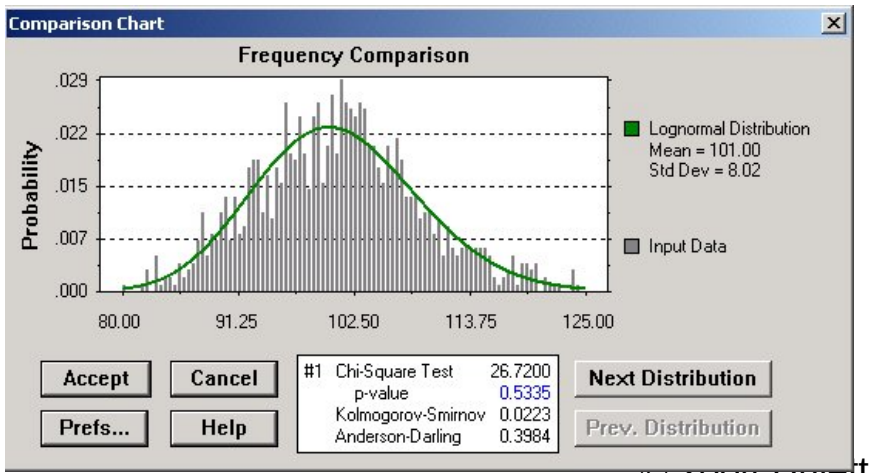
- Input the duration risk results into the MS Excel spreadsheet that contains the cost model
  - Fit the available Crystal Ball® functions to the 1,000 iteration results for phase durations
  - Input the fit distributions as assumptions to the cost risk model
  - Add interview results for the burn rate uncertainty in the cost model

Estimate the Best-Fitting Distribution Available in Crystal Ball for Summary Task Durations

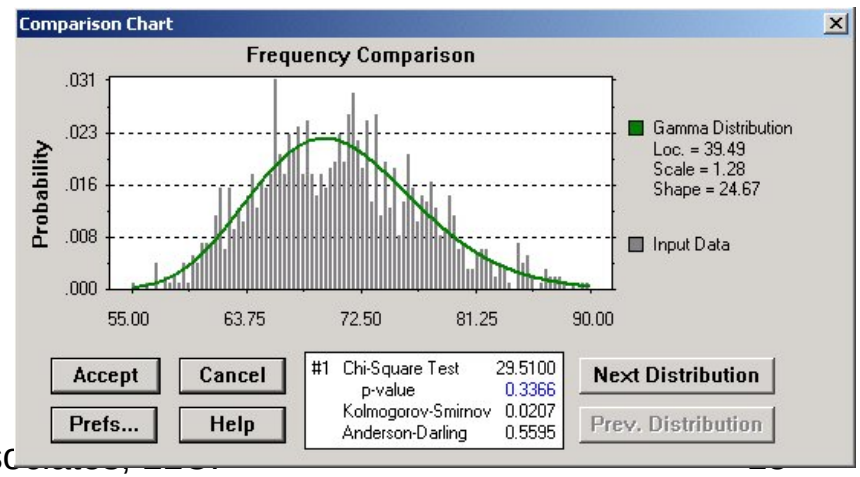
Component 1: Lognormal



Component 2: Lognormal



Integration and Test: Gamma



Baseline Cost Estimate from the Resource Loaded and Priced Schedule

Activity	Estimated Cost
	(000)
Integrated Cost-Schedule Project	**$1,629**
Component 1	**$557**
Design 1	$101
Build 1	$288
Test 1	$168
Component 2	**$461**
Design 2	$161
Build 2	$195
Test 2	$105
Integration and Test	**$611**
Integrate	$422
System Test	$189

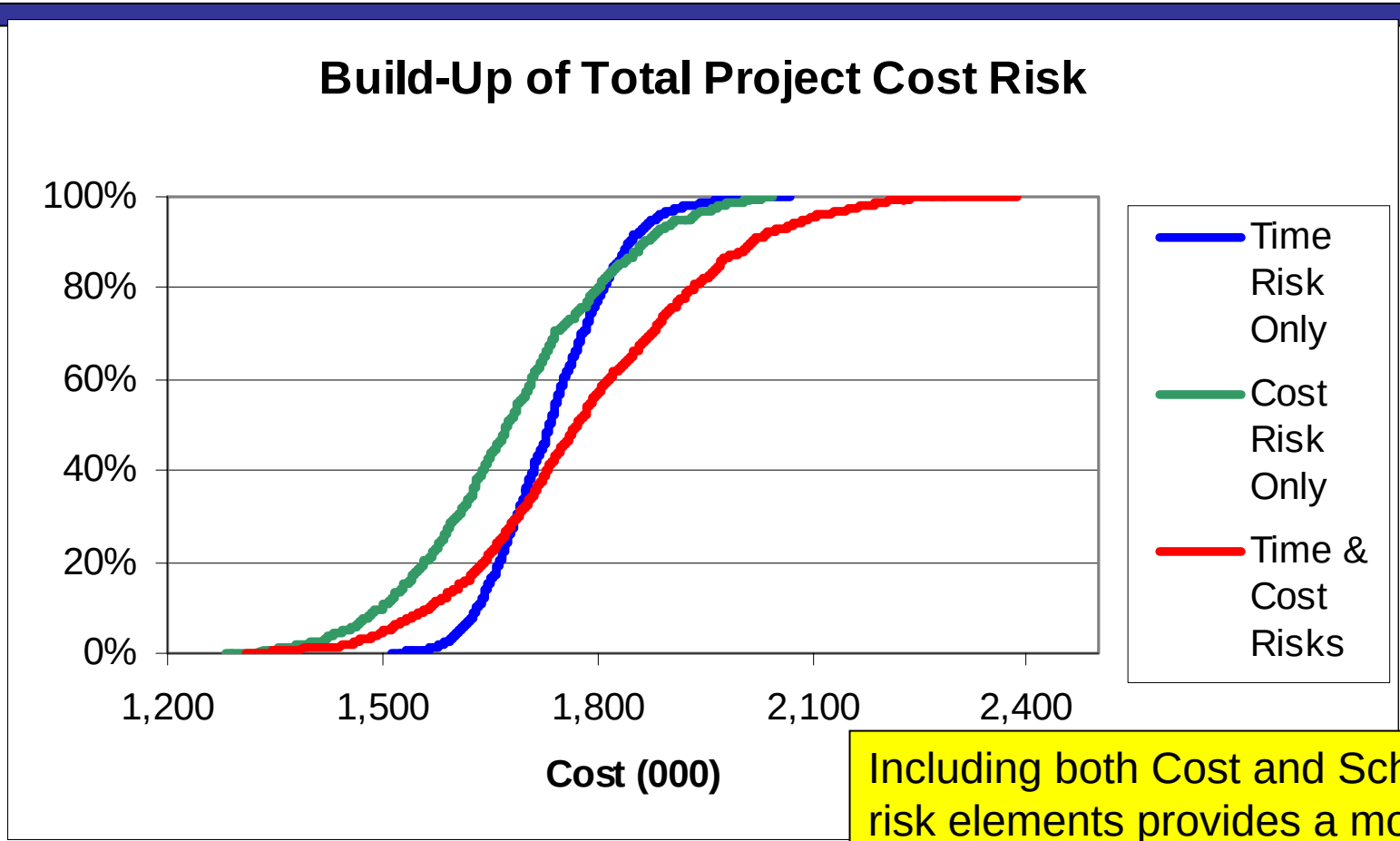
Cost is $1,629,000 if everything goes "according to plan"

Combine Duration Burn Rate Risks: Component 1 Example

Component 1	Baseline Estimate Cost (000)	Low	Most Likely	High
Avg. Workers per day	8.1	6	8	12
Avg. Rate / Hour	88.1	80	88	91
Duration from Schedule	98.0	Est. Lognormal distribution		
Component 1 Cost	**557**			

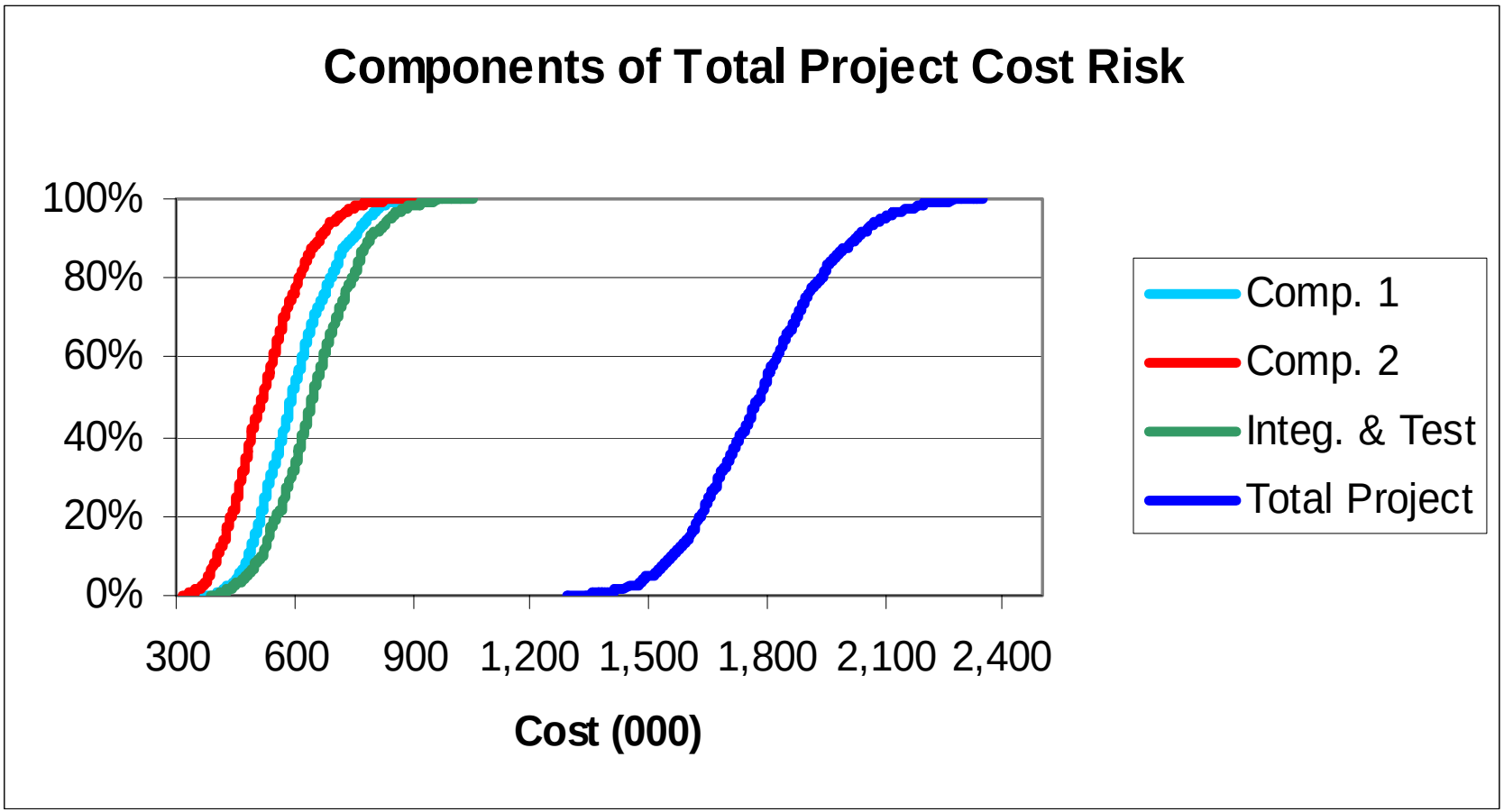
The Lognormal distribution was estimated from the 1,000 duration results for Component 1

Cost Risk With Cost Elements', Schedule Elements' and All Elements' Risk Included

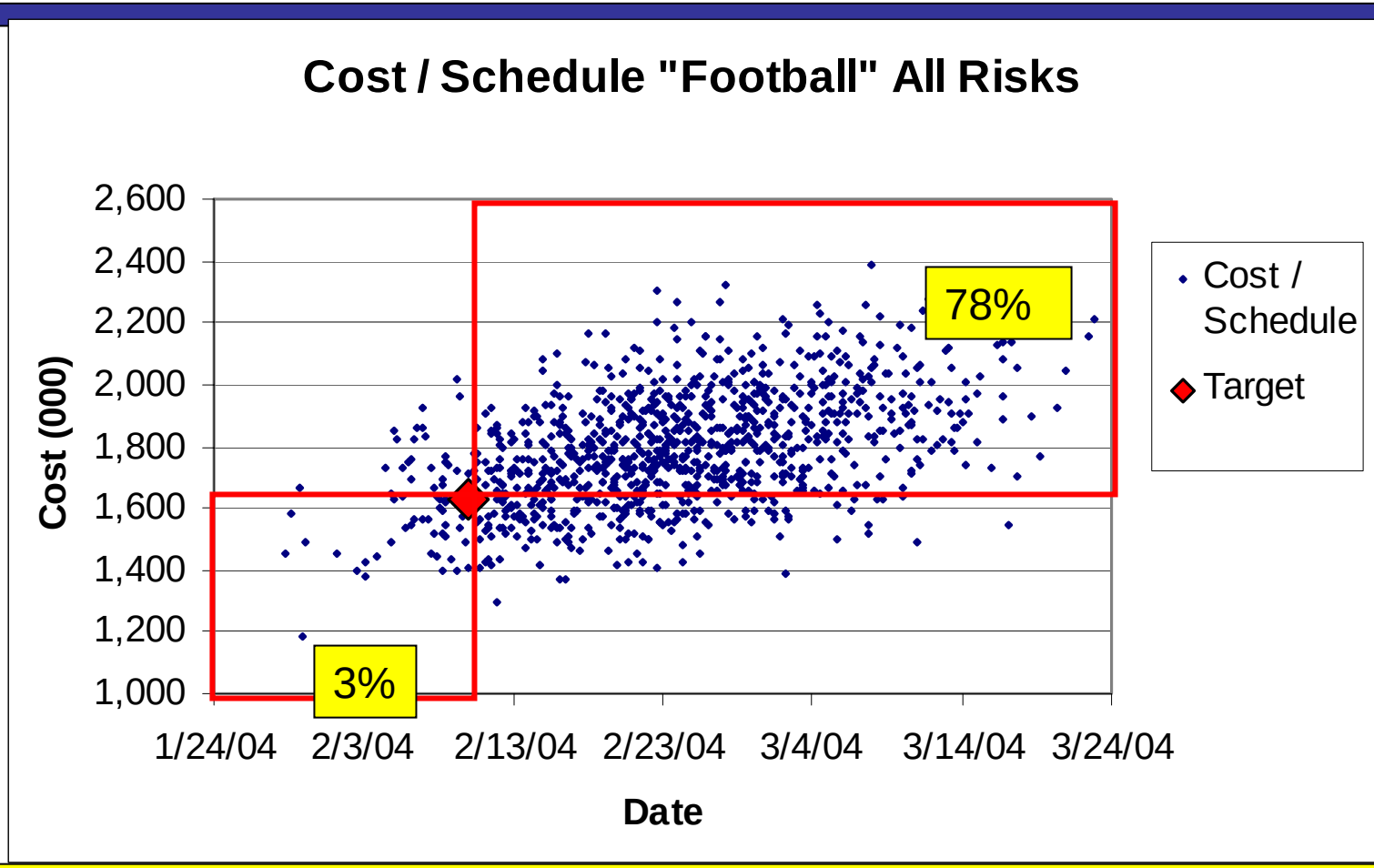


Including both Cost and Schedule risk elements provides a more complete estimate of cost risk

Components of Total Project Cost Risk



Picture of a Troubled Project



Joint scatter plot of cost and schedule compared to the baseline estimates without risk. For this plot we have to schedule in Excel, a risky business

Computing Schedule Risk when Cost and Schedule are in the Scheduling Program

- Resources are identified and their hourly or daily cost are input into the scheduling software
- Resources are assigned to tasks and costs of those tasks and the total project are computed
- Uncertainty can be added by:
  - Probability distribution of the duration
  - Probability distribution of the burn rate
- Jointly simulate the cost and schedule in the program

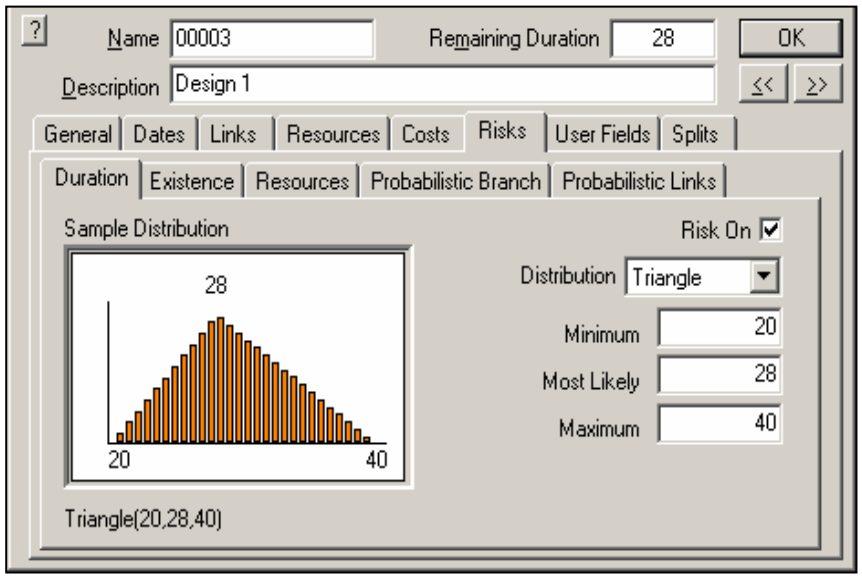
Cost and Cost Risk in Scheduling Software

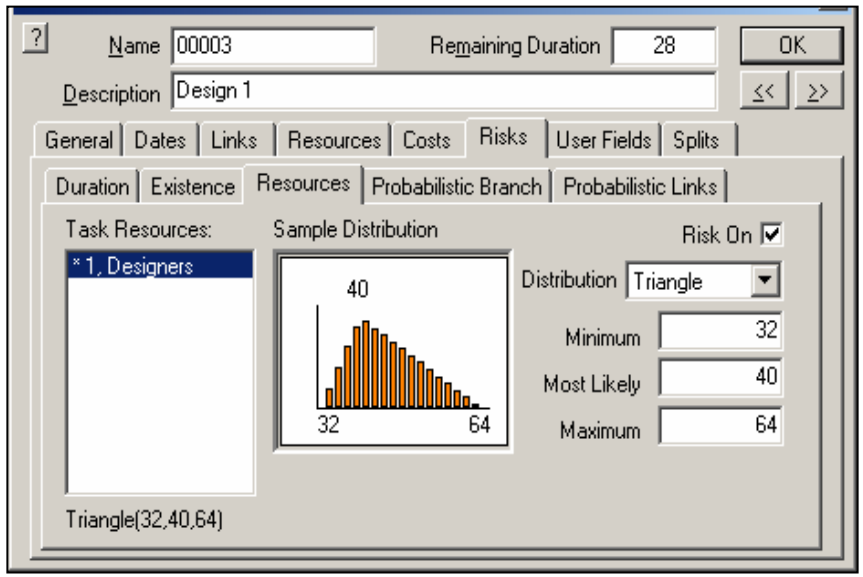
Task Name	Duration	Description	Comment
00002	98	Component 1	00002

Resources	Code	Number	Dur	Rate	Labour cost	Material cost	Other	Total
Designers	1	40	28	$90	$100,800			$100,800
Builders	2	80	45	$80	$288,000			$288,000
Testers	3	64	25	$105	$168,000			$168,000
					$556,800	$0	$0	$556,800

Examples of Component 1 resource loading included in scheduling software – Pertmaster®

Add Duration and Burn Rate Uncertainty

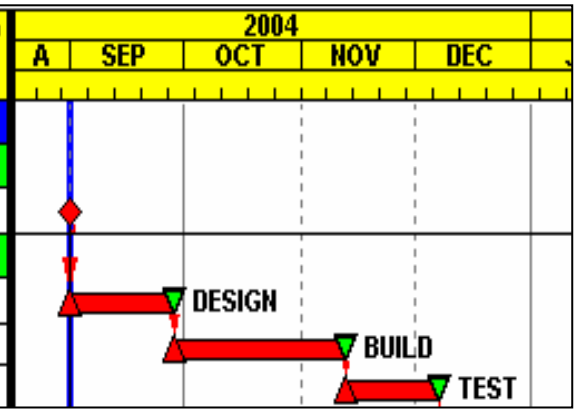




Examples of Component 1 duration and burn rate uncertainty included in scheduling software – Pertmaster®

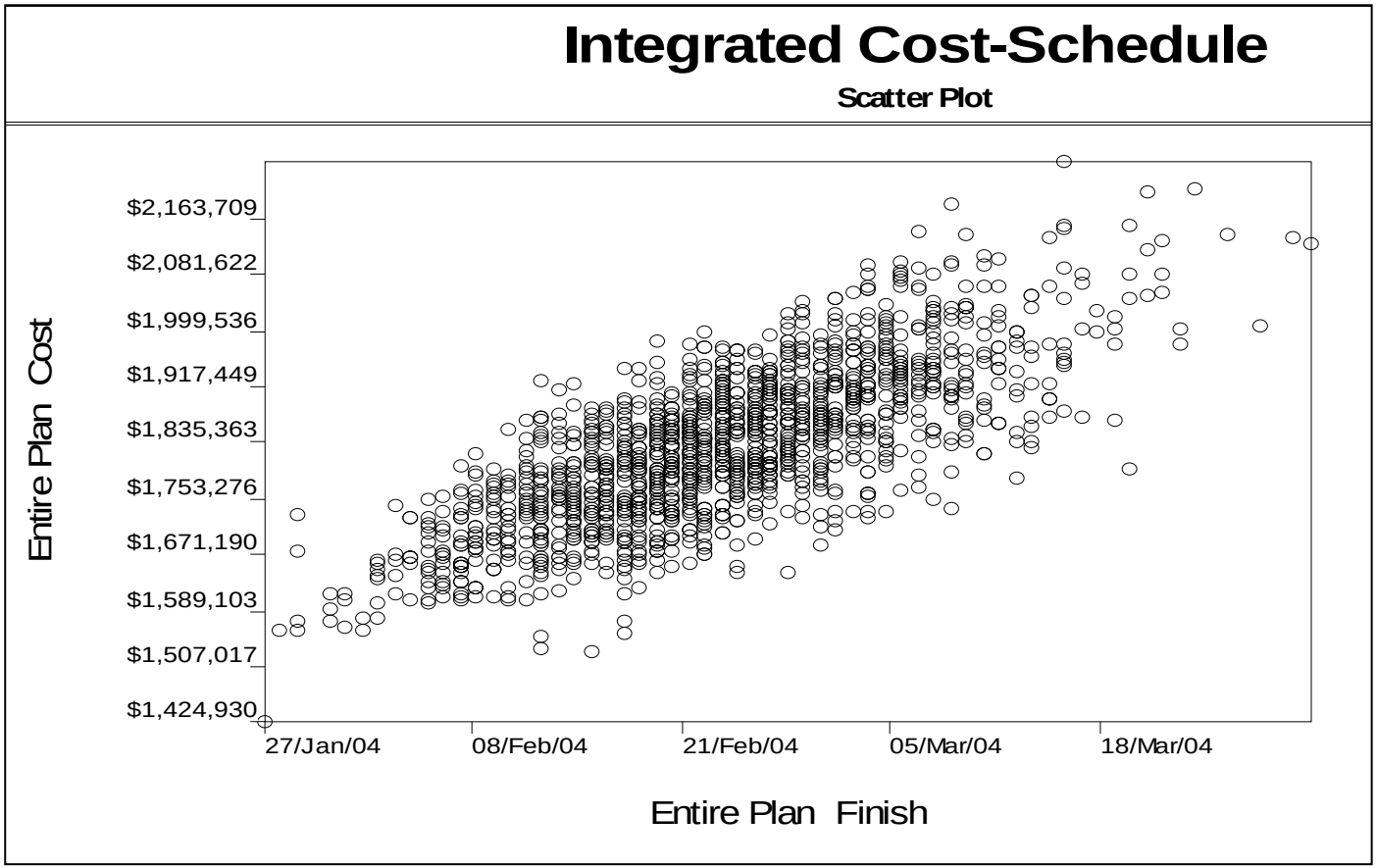
Cost and Cost Risk in Scheduling Software

Activity ID	Activity Description	Orig Dur	OPTD	MOST	PESS	Resource	Budgeted Cost	ROPT	RMST	RPES	RESO
ntegrated Cost / Schedule Risk PMI											
A1											
START	Project Start	0					0				
C1											
C1 DESN	Design 1	28	20	28	40	DESIGN	100,800	4	5	8	U
C1 BLD	Build 1	45	35	45	55	BUILD	288,000	9	10	13	U
C1 TST	Test 1	25	15	25	40	TEST	168,000	7	8	10	U



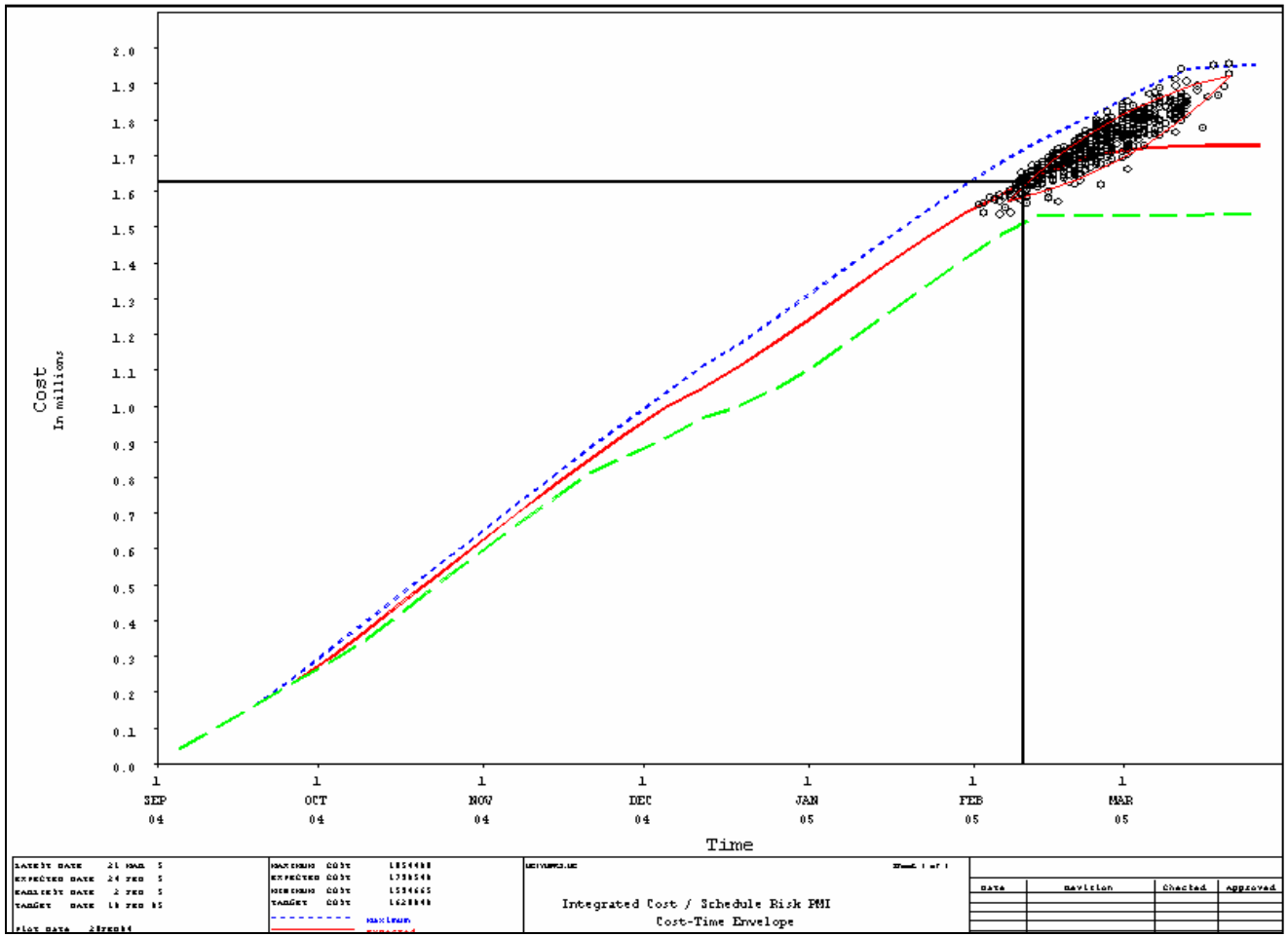
Examples of Component 1 resources, costs, and time and burn rate uncertainty included in scheduling software – Monte Carlo®

Integrated Cost and Schedule Risk Results



Date and Cost Scatter plot from Pertmaster® schedule risk software

Integrated Cost and Schedule Risk Results



Date and Cost Scatter plot from Monte Carlo® schedule risk software

Summary of Main Principles

- Cost risk depends on elements of schedule uncertainty
- The cost estimate is not secure if the schedule is slipping
- Distinguishing the schedule risk elements and their impact on the cost estimate risk provides a more accurate picture of cost risk
- Data gathering on burn rate demands new thinking

Technical Summary

- Cost estimation is often conducted at a level more summary than scheduling
- If the resources and cost are not included in the schedule
  - Estimating duration uncertainty of a summary task using a schedule risk analysis program
  - Use fitted probability distribution of duration as an input to the cost risk model
  - Add burn rate uncertainty
- There are other costs that are not sensitive to time. We have not analyzed those in this paper

Technical Summary (continued)

- If the resources are loaded and priced in the schedule software, at least two schedule risk packages can perform the integrated cost / schedule risk analysis
- Simultaneous simulation ensures that the concepts and the results are consistent
- Not many schedules have fully-loaded and priced out the resources, however

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